Mr. Newcomb at the end of his paper
that it wd. seem impossible to set a charged
sphere moving as fast as light. The reason
for this conclusion seems to be that the
energy is then infinite, & as it is derived from
external source actg the body moving, an
∞ amt. of work is req., or an ∞ resistance
wd. be experienced.

This is a fallacy. The mechanism is
not rigid but elastically yielding, or acting
equivalent. Also regards the ether itself & whether
it is mech. possible wd. permit bodies of matter
thro' it at velocities of light, we know nothing.
But that is not the q., which is simply one of
applic. of the two circuital laws assumed to
hold good at any speed. There is nothing to
prevent a charge going thro' the ether at any
velocity whether the speed of light or above it.
& the question of disinclination of energy does
not enter into it. Consider this case. A sphere
with a charged body sticking, with static distrib.
of displt. Then move it, & let its motion
follow any law whatever, finally settling to a
definite steady speed whatever. Now wait
a bit, and the special distribution round the
instantaneous position of the sphere will be
assumed. But it cannot extend to ∞ in the next moment
Beyond the distance travelled by
light in the time occupied in going from one
to other place, there is up to that moment,
no disturbance at all of the original distr.
This holds for all time, so that the energy
is always finite, even when the speed is
that of light, or more than it.

Where does the energy come from? Any
assumed increase, that is the body meets
with resistance or its velocity is increased.
Not any that, but it requires force to maintain
its motion steady, until the steady distr.
appropriate to the velocity is assumed. But
those the forces exert while the sphere is getting
up the speed will drive to one where
the velocity of the body is less than light, it will
not do so when = v. The causes is that the
tubes of el. force are a little more crowded on
the rear side than on the forward side. They
tend to produce what may be considered lateral.
They are left behind by the body with less vel.
The effect is to pull the sphere back.
When u < v there the maintenance of a constant
velocity will tend to the vanishing of the force. When
u = v, it still left a single charged sphere would
always have a pull back left. But there is no
need to have any one body. Have two. Then the
energy, even the ultimate energy is finite, &
there is no trouble. u = v still leads to

finite equilibrium & plane wave.

But when u > v the pull back becomes
formidable at once. It remains even when
the steady state is assumed (that is, to
a great distance approximately). The displt.
is a conical sheet, behind the charge
with a supplementary distribution inside the cone.
The pull back is steady. That is the charge
if not forced, will be brought ultimately
to the speed of light. But if forced, then
its speed would then thereafter be a
steady waste of energy going on, represented
by the formation of constant generation
of the cone at its apex, and departure of
energy outwards normally with the surface of the cone as
it grows.

This was the state of things suspected by
me in 1888 (El. Pap. v. 2 . p), and
I have since confirmed it mathematically.
~~There are no infinities except at infinity~~
The state of displt. is described El. Pap. v. 2 p.
when u > v. It works out all right,
& with no infinities when applied to
some concrete cases when the velocity of a
point charge.

To exemplify my meaning, say a
charged body is suddenly brought from rest to a
state of motion v. Then the displt. will consist of the old distribution
going up the old positions of the spheres
and then suddenly going straight round at the time
of motion to the new positions.

Note by
Heaviside
Dr. Oliver

Proof (confidential) for the use of Members of the Physical Society only.

. *Attenuation of Electric Waves along Wires and their Reflection at the Oscillator.* *By* EDWIN H. BARTON, *D.Sc., F.R.S.E., Senior Lecturer in Physics at University College, Nottingham.*

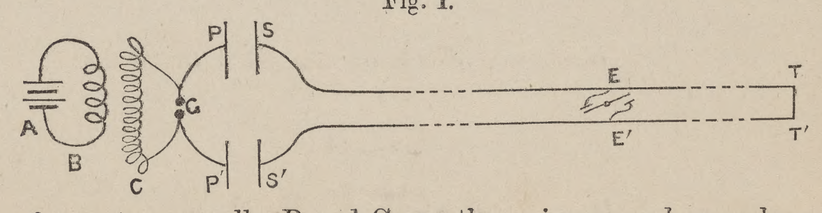
LAST year Mr. Bryan and the present author realized experimentally the absorption by a terminal bridge of the electric waves incident upon it*. The first application

* Proc. Phys. Soc. vol. xv. pp. 23-30, 1897; Phil. Mag. [5] xliii. pp. 39-45, 1897.

of this result which suggested itself was the use of such a bridge in determining the attenuation (or rate of decay) of the waves along their parallel leads. For, if one can at pleasure either (1) practically absorb the waves, or (2) reflect them practically undiminished, a suitable electrometer being inserted in the line, we have in the first case a single passage of the wave-train past the electrometer, and in the second a number of passages of the wave-train until it is practically quenched by its repeated losses. Thus, the electrometer in the second case is affected by the sum to infinity of two geometrical progressions, viz., those due to the forward and return waves respectively. Whereas in the first case, when the waves are absorbed at the end of the line, the electrometer is affected by the first term only of one of the above series. Hence the ratio of the electrometer-throws in the two cases is a function of the attenuation constant and the dimensions of the line, and would appear to be immediately calculable. But this is not all. For the above is on the assumption that the losses occurred only along the wires themselves, whereas something is lost also on reflection at the primary oscillator where the waves are generated. This fact soon became apparent on the repetition of the experiment with different lengths of line, and the value of this reflection coefficient was substantially confirmed by further experiments and by the application of this new view of the case to experiments previously carried out in Bonn.

Experimental Arrangement.—The arrangement of the apparatus adopted in the determination is diagrammatically represented in fig. 1. In this figure, A denotes the battery

Fig. 1.



of two storage-cells, B and C are the primary and secondary coils respectively of the induction-coil of which C has a resistance of 3000 ohms and an inductance of about 20 henries. G is the spark-gap, which was adjusted to 2 mm. The wire PGP′, measured along the semicircle, was about 2 m. PP′ are condenser-plates of zinc 40 cm. diam. placed opposite to and 30 cm. distant from the precisely similar plates S S′. The line is represented by S E T T′ E′ S′, and consists of two parallel copper wires 1·5 mm. diam., and kept 8 cm. apart by wood separators at intervals of about 2 m. E E′ denotes the electrometer, which has a single plane needle, initially uncharged, and suspended by a fine quartz fibre between two disks attached to the line at E and E′. The needle is therefore electrified by induction whenever a wave passes E E′, and its ends are consequently attracted to the disks whatever the sign of their potential difference. T T′ signifies the several pieces of apparatus successively used at or near the end of the line, and will be described in detail for each case when dealt with. The lengths of the line before and after the electrometer will also be stated in connexion with each experiment. The waves generated by the primary oscillator were about 8·5 m. long.

Theory.—Let δ_1 be the electrometer-throw obtained when a completely absorbing bridge is used at T T′ (fig. 1), and let δ_2 be the throw when a "no-resistance" bridge is used at T T′, *i. e.*, a piece of short thick copper wire, which therefore reflects the waves without appreciable loss. Then it is required to express the ratio δ_2/δ_1 as a function of the attenuation and reflection coefficients and then, from the experimental values of the above ratio, to solve the resulting equations for the coefficients sought.

Let the maximum potential difference of the two wires of the line due to any wave be taken as the amplitude of that wave, let ρ be the factor by which the amplitude of a wave is affected on reflection from S S′ (fig. 1), and let $e^{-\sigma x}$ be the attenuation factor by which the amplitude is affected in traversing x cms. of the line. For convenience of actual working $10^{-sx'}$ was substituted for the above, x' denoting length traversed in metres, σ was then deduced from s.

Now the throws of the electrometer are proportional to the time-integral of the square of the amplitude of the passing-wave train, *i. e.*, proportional to its energy: hence, if the lengths of the line before and after the electrometer are l_1 and l_2 respectively, and a wave-train of initial energy i leaves the oscillator, we have with the "absorber" at the end of the line

$$ie^{-2l_1\sigma}=k\delta_1, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where k is the electrometer constant.

Again, with the no-resistance bridge or short circuit at the end, we have two series of impulses at the electrometer, the energy of the forward waves being

$$ie^{-2l_1\sigma}[1+\rho^2e^{-4(l_1+l_2)\sigma}+\ldots],$$

and that of the backward ones $[e^{-4l_2\sigma}]$ times the above. Hence we obtain

$$\frac{ie^{-2l_1\sigma}(1+e^{-4l_2\sigma})}{1-\rho^2e^{-4(l_1+l_2)\sigma}}=k\delta_2, \quad . \quad . \quad . \quad . \quad . \quad (2)$$

whence

$$\delta_2/\delta_1=\frac{1+e^{-4l_2\sigma}}{1-\rho^2e^{-4l\sigma}}=r \text{ say}, \quad . \quad . \quad . \quad . \quad (3)$$

l being written for l_1+l_2.

Two experiments with different values of l_1 and l_2 furnish two equations like (3); these are then cast in the form

$$\rho^2re^{-4l\sigma}=r-1-e^{-4l_2\sigma}, \quad . \quad . \quad . \quad . \quad . \quad (4)$$

and ρ^2 eliminated between them. The result was an equation in σ of the form

$$A_1e^{-a_1\sigma}+A_2e^{-a_2\sigma}+\ldots=0,$$

or say

$$u=0.$$

Various trial values were then given to σ and plotted as abscissæ of a curve, the corresponding values of u being its ordinates. The value of σ satisfying the equation was thus found graphically as that at which the curve cut the axis of abscissæ.

Experiments.—In the experiments the bridge used as an absorber was placed absolutely at the end of the line, as it is only when in that position that it can absorb all. It consisted of pencil marks on a ground glass disc as previously described, and before use each time was carefully adjusted to the requisite resistance for absorption as mentioned in the paper already referred to. A doubt has been expressed as to the constancy of the value obtained for a resistance of this kind by the Post-Office box, some similar resistances having been said to measure differently according to the voltage used in the test. Probably this might be the case to a slight extent if extreme variations were used, but with the pencil-mark resistances employed in this work no change of value was observable, whether a single Leclanché cell was used or a battery of several storage-cells, so that the resistance was determined with all the accuracy needed for the present purpose.

The other bridge, intended to reflect undiminished the waves incident upon it, was placed a little short of the end of the line, and occupied alternately two positions a quarter of a wave-length apart. This precaution was adopted lest, for as the bridge was beyond the electrometer, the head of the wave-train reflected from the bridge might reach the electrometer before the tail had passed it. In this case a slight interference would arise at the electrometer, and its throws would not be of the values due to simple passages and re-passages of the wave-train. By using the above two positions for the bridge this source of error is obviated, for, if one gave additive interference at the electrometer, the other would give about equal subtractive interference, and their mean would be the result desired as though no interference had occurred.

The length l_2 is of course measured from the electrometer to the point midway between these two positions of the bridge.

Further, to eliminate errors due to the unavoidable irregularity of the sparking in the primary oscillator, a number of readings, about 20, with the absorber only at the end of the line were alternated with a like number of readings with the reflecting bridge interposed. The separate ratios of the electrometer-throws obtained under the two conditions were then taken, and the probable error of their arithmetic mean calculated by the theory of probabilities.

Observations and Results.—Four such sets of readings were taken with different values of l_1 and l_2. One set is shown in Table I., and the data and results of the whole four summarized in Table II.

TABLE I., showing readings for $l_1=117{\cdot}5$ m. and $l_2=48$ m.

Electrometer-throws with *Absorbing Bridge* only at end of line.		Electrometer-throws with Reflecting Bridge		Ratios of throws, viz.:—		Mean Ratios.
Actual observations.	Interpolated Means.	at 48 m.$-\frac{\lambda}{8}$ beyond the Electrometer.	at 48 m.$+\frac{\lambda}{8}$ beyond the Electrometer.	col. 3 / col. 2	col. 4 / col. 2	
11						
	13	43		3·307		
15						
	16·5		44		2·666	2·986
18						
	17·5	42		2·400		
17						
	18·5		36		1·946	2·173
20						
	18	41		2·277		
16						
	15		44		2·933	2·605
14						
	16	33		2·062		
18						
	15		33		2·200	2·131
12						
	12·5	32		2·560		
13						
	12		28		2·333	2·446
11						
	13·5	27		2·000		
16						
	18·5		46		2·486	2·243
21						
	22	55		2·500		
23						
	22		48		2·181	2·340
21						
	20·5	56		2·731		
20						
	20		43		2·155	2·443
20						
	20	57		2·850		
20						
	21		52		2·476	2·663
22						
	21·5	50		2·325		
21						
	21·5		49		2·279	2·302
22						
		Whence Final Mean Ratio = 2·43±0·05.				

Say $\frac{R}{2Lv} = .0000013$ / 1.000000 / 769.23 metres

$L = 15$ to 20

$2L = 30$ to 40

$\frac{R}{v} = .00039$ to $.00052$ per cent^{m}

$= .039$ to $.052$ per metre

$= 39$ to 52 per kilom.

say 40 to 50 $\therefore R = 40$ to 50×30 ohms

$= 1200$ to 1500 ohms per Kil.

two wires

1.5 mm = .15 centim. diam. rad. = .075 cent

$\frac{1600}{3.1416 \times (.075)^2} = \frac{1600}{\frac{22}{7}(.0056)}$

$= \frac{11200}{1232}$

.0056 / 22 / 112 / 112 / 1232

1232 / 11.2 x 10^6 (10^5 metres

176 / 16,000,000

10^5 per centim

10^{10} per K^{m}tres = 10 ohms

one wire

2 wires make 20 ohms per Kil.

$\therefore$ multiplier 60 to 75 times

$R' = (\frac{1}{2} R_{(ohm)})^{\frac{1}{2}}$

$= (\pi R_H f)^{\frac{1}{2}}$

$R = 10^6$ ohms per centim.

$\frac{R'}{R} = (\frac{\pi R_H f}{R})^{\frac{1}{2}}$

$(6 \text{ to } 7\frac{1}{2})^2 = \frac{\frac{22}{7} f}{20^6}$

$\lambda = v\tau = \frac{v}{f}$

$f = \frac{v}{\lambda}$

$(36 \text{ to } 56) \times 20^6 \times \frac{7}{22} = f$

means $280^6 = f$

$8\frac{1}{2}$ m. = 850 cm.

850 / 30000,0^6 / 35 millions

450

+ 40,0^6

actual frequency.

~~30 to 40 billions~~

$\left(\frac{R'}{R}\right) = \left(\frac{\mu\pi f}{R}\right)^{\frac{1}{2}} = \left(\frac{\frac{22}{7} \times 350^6}{10^6}\right)^{\frac{1}{2}}$

one wire.

$= \sqrt{110} = 10.5$

Instead of 10.5 multiplication. ~~60 to 75~~

~~Perhaps one wire of the two mind.~~

There is a large loss.

$\frac{R'}{2Lv} = \frac{R'}{900 \text{ to } 1200 \text{ ohms}} = .0000013$

R' ohms $= .0117$ to $.0156$ 10^9

10^4

$= 11.7$ to 15.6 millions.

calculated per cent^{l} of

Calculated per Km of wire 20^5 per cent.

Ratio $\frac{117 \text{ to } 156}{2} = 58$ to 78 multiplier

Best Lord R's formula gives only 10.5.

If we had been interesting if D2B had made comparison of the observed attenuation with that to in the transit of waves with that to be expected in the long wave theory.

Then $\varepsilon^{-\sigma x}$ is the attenuation. Here

$\sigma = R/2Lv$ when no leakage

R is the steady res. of the two wires per unit length, when waves are very long & this will not do at all. But if the disturbances are simply periodic & damped long continued then $\sigma = R'/2Lv$ when R' is the effective resistance $(\frac{1}{2} R_{(ohm)})^{\frac{1}{2}}$ acts to high frequency $\alpha = 2\pi f$ f = frequency. This implies that the E.M. state is set up & continued so in the case of a wave train entering say S wire (no practical reflection) we should have an ~~exponential~~ attenuation of the front of the wave train gradually falling to the above value R' behind. But it is difficult to be at all definite in this matter, considering the meaning to the cause of attenuation.

Making a rough comparison, & assuming the steady res. to be 20 ohms per Kilom. for both wires or 10^5 per cm. each wire and assuming L to be 15 to 20 cm. then R' comes to $10.5 \times R$.

But by $\sigma = .0000013$

& the same L I get

$R' = 1200$ to 1500 ohms per Kil.

i.e. 60 to 75 times R.

This is a very great difference indeed, & (unless there is some mistake in these figures) requires elucidation to explain why it is so great.

We must not expect anything like such good agreement as in the case of Liquid absorption of energy by a pencil multiply reflected because attenuation by the line itself is a more complicated business, & the above formula perhaps assume a great deal more than is warranted.

TABLE II., summarizing Data and Results of Experiments.

Lengths of line before Electrometer $=l_1$.	Lengths of line after Electrometer $=l_2$.	Ratio of Throws $=r$.	The unknown quantities for which the equations were actually solved. s.	The unknown quantities for which the equations were actually solved. ρ^2.	Attenuation Constant. σ.	Reflection Coefficient. ρ.	Remarks.
metres.	metres.						
117·5	20	2·41 ±0·04	0·00564	0·4776	0·0000130	0·69	As these were the best sets of observations the resulting equations were solved simultaneously.
65·0	20	2·744±0·035					
65·0	48	2·64 ±0·18	0·0005	0·53	0·0000115	0·73	This being the worst set of readings (as seen by the large probable error) was treated alone. Any *number* of pairs of values could, of course, be found that would satisfy the equation.
117·5	48	2·43 ±0·05	0·00043	0·4776	0·000010	0·69	This is the set given in Table I., and is seen to be slightly less trustworthy than those at the head of this table. Two solutions are given of this set, the first seems the more probable.
			0·0005	0·555	0·0000115	0·745	

It may be interesting to regard, in the light of the results in the second table, two sets of observations taken by the writer in Bonn during the summer of 1893 while working under the late Professor Hertz*. In the course of those experiments (directed primarily to an object quite different from that now under discussion) the electrometer was placed almost at the end of the line. By an entirely different method from that now adopted, ratios were obtained for the electrometer-throws due (1) to the passage past it of the sum to infinity of the geometrical progressions formed by the outward and return waves, and that due (2) to the single passage of the initial wave train. The lengths of the line to the electrometer in the two cases were 160 and 91·5 m. respectively, and the corresponding ratios were 1 : 0·34 and 1 : 0·31. Hence for this case equation (4) takes the form

$$\rho^2 r e^{-4l\sigma} = r - 2, \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

since $l_2 = 0$.

Solving simultaneously the two equations thus derived from the experimental values of r, we obtain

$$\left.\begin{aligned} s &= 0{\cdot}00027, \quad \rho^2 = 0{\cdot}476, \\ \sigma &= 0{\cdot}0000062 \text{ and } \rho = 0{\cdot}69 \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (6)$$

In these experiments the primary oscillator as regards the parts SPGP′S′ (fig. 1) were precisely the same as in the present paper, and it seems noteworthy that its reflection coefficient is practically the same. The values of the resistance and inductance of the secondary circuit of the induction-coil used in Bonn cannot be stated, as they were not at the time regarded as of any material consequence and accordingly were not measured.

It will be seen that the attenuation constant in the 1893 case is about half that in the present work. This may possibly be due to the wood separators used along the line being much drier in a German summer than in an English winter and spring.

Comparisons with Heaviside's long-wave theory of reflection.—After obtaining experimentally the unexpected result that of the wave energy incident upon the primary oscillator only about one-half or less was reflected along the line, it seemed incumbent on one to test this if possible by theory. And in this connexion I have pleasure in acknowledging my indebtedness to Mr. Oliver Heaviside for explanation of his theory applied to the case of reflection from a terminal arrangement prior to its publication*.

On Heaviside's theory developed originally for long waves, say of telephonic frequency, we have for the reflection coefficient

$$\rho = \frac{Z - Lv}{Z + Lv}, \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

where Z is the resistance operator, L is the inductance per unit length of the line, and v is the speed of light.

Now the resistance operator in the case of condensers, secondary and primary coils is given by

$$Z = \frac{1}{Sp} + (R_2 + L_2 p) - \frac{M^2 p^2}{R_1 + L_1 p}, \quad . \quad . \quad . \quad (8)$$

* Proc. Roy. Soc. vol. lvii. pp. 72 & 75 (1895); D.Sc. Thesis for the University of London, 1894, pp. 20–22 and 28-29; Wied. *Ann.* Bd. liii. pp. 525–527 and 528–529 (1894).

* 'Electromagnetic Theory,' pp. 786–9; 'The Electrician,' April 9, 1897.

where S is the capacity of the condenser, the R's are the resistances and the L's the inductances of the coils, M their mutual inductance, and p the time differentiator.

Of the three terms on the right-hand side of (8), the first only is to be used if the arrangement is short-circuited at the spark-gap, G (fig. 1), the first and second only if the primary circuit of the induction-coil is open, but all three if the primary is closed.

Now in the actual experimental case the sparks at the primary oscillator are started by the break of the primary circuit of the induction-coil, the interruptor remaining open during the greater part of its period (say the $\frac{1}{30}$ of a second). But the time required for the wave train to pass to the end of the longest line used and back again, say a dozen times (which practically extinguishes it), is only of the order 14 millionths of a second. Hence the form of (8) to be adopted as applicable to the present case is

$$Z = \frac{1}{Sp} + R_2 + L_2 p, \quad . \quad . \quad . \quad . \quad . \quad (9)$$

if indeed the long-wave theory holds at all for waves so short as 8 or 9 m.

But, on working from equation (9) the value of ρ, one obtains a result differing from unity by less than 1 in 10^{10}.

It would appear therefore that the long-wave fails to apply to the present case of high-frequency waves and their reflection from condensers and coils of high inductance, each of which involves of course the time-differentiator.

In the case of a resistance practically devoid of inductance, on the other hand, as was seen in the last paper on the absorbing bridge, the long-wave theory seems to hold within a close approximation.

Reflection from Condenser only.—However, in order to experimentally test the matter a little further, a second set of plates like PP′ SS′ (fig. 1) was made and put up at the end of the circuit at TT′, but this set had simply one wire in the form of a semicircle to connect the far plates instead a spark-gap as at G. The induction-coil was also omitted entirely at this end of the line.

Hence the long-wave theory for reflection for this arrangement gives $Z = 1/Sp$ and

$$\rho = \frac{1/Sp - Lv}{1/Sp + Lv}, \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

And this equation, applied to an incident wave of the type $\phi_1 \sin nt$, gives for the reflected wave $\phi' \sin(nt + \alpha)$, where

$$\left.\begin{aligned} \phi'/\phi &= \rho = 1, \\ \text{and} \qquad \tan\alpha &= \frac{-2LvSn}{1-(LvSn)^2} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (11)$$

Here then is an opportunity of comparing simply the behaviour of the short waves with what may rightly be expected of the longer ones. For in this arrangement there is no spark-gap whose heated state in the former case leaves one in some doubt as to how far, when the waves return to it, it acts as a short circuit and so possibly cuts out the induction-coil entirely.

The experiment was now conducted by alternating electrometer readings (1) with the condenser at the terminus, and (2) with a no-resistance bridge placed across the wires just before the end of the line.

If then the condenser reflected all, as by equations (10) and (11) must be the case with long waves of the simple harmonic type whatever the capacity of the condenser, we should find the ratio of the electrometer-throws taken under the two conditions to be unity. Whereas the experiment gave the ratio of throws with no-resistance bridge to those with condenser only to be 1·26 ± 0·07, the lengths of the line before and after the electrometer being 117·5 m. and 45 m. respectively. Applying now to this case the theory of the phenomena analogous to that developed in the early portion of this paper, and substituting for ρ^2 and s in the equation so derived the values 0·4776 and 0·000564 as shown in Table II., we obtain for the reflection coefficient of the condensers alone

$$\rho' = 0{\cdot}82 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

This value, while differing but little from that of ρ for the condensers, spark-gap, and induction-coil at the oscillator, differs in the direction that one might anticipate. It also supports the value previously found for ρ, in that ρ' though greater than ρ is still distinctly less than unity. It will be seen from the end of the article in 'The Electrician,' April 9th, 1897, that Mr. Heaviside scarcely expected the long-wave theory to be valid for the high-frequency waves here used.

Conclusion.—The chief results arrived at may be thus summarized :—

1. The value of the attenuation constant σ for the line experimented upon and the waves in use is of the order 0·000013, where the amplitude of the waves is affected by the factor $e^{-\sigma x}$ in traversing x cm. of the line. The energy of the waves is thus reduced to half by traversing about 250 m. of the line.

2. The reflection coefficient applicable to the primary oscillator and induction-coil as used to generate the waves is of the order 0·69, or rather more than half the energy is lost on reflection. The reflection coefficient of a precisely similar arrangement of condenser-plates but devoid of spark-gap and induction-coil is rather greater but still distinctly less than unity. On the long-wave theory the second of these reflection coefficients would be precisely equal to unity and the first of them practically so.

I have to thank Mr. H. H. Ratcliff for help at the beginning of this work, and especially Mr. R. S. Willows for his valuable assistance at the later experiments and their reduction.

University College, Nottingham,
May, 1897.

POST CARD

Mrs J.F.J. Bethwood,
15 Rue Michel Ange (16e)
Paris.

(France)

Homefield
Torquay
England.
13.4.19.

You have acknowledged up to p. 11. But I have sent up to p-32. I dont know whether you get it (2 days is enough) so have left off.

Oliver Heaviside

I rec^d (registered) 5.4.19 "Belated" on 10.4.19 card and the x Someone has given a copy of the Belated to the Local Paper. He calls me a Townsman. I repudiate that. But the Bumptious Poor Man calls me a fellow townsman, which is worse beyond measure.

Why do registered take 5 days. and ordinary only 2? Thursday mark 5.4.19 last night

I have duly received the Belated Letter and returned it

of dealing with these and similar more advanced problems is of importance. I assert that by its means problems can be attacked and successfully solved with greater power than by any other known method. Furthermore, that it is essentially simple in operation; so that, although it goes deeper, yet it requires less work and less mathematics of the complicated kind. And, finally, that it is for the above reasons and others quite practical. It is rather disagreeable to have to be self-assertive and dogmatic (especially when one thinks of the always possible risk of error); but there may be times when it becomes a duty—*e.g.*, when mathematical rigourists are obstructive.*

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* [March 21, 1895.] After writing the above, Prof. Perry wrote asking about the case of capacity and conductivity functions of the temperature, saying, "X. says he can't do it, doesn't know anyone who can, and is sure *you* can't." The general case is perhaps hard, but I found at once that when c and k vary together, according to any power, integral or fractional, of the temperature, the solution was quite easy, the characteristic becoming linear. This is obvious when done. I sent Perry some solutions of this kind. He then himself extended the matter by taking c and k to be any similar functions of the temperature. This is also obvious when done (Perry, *Nature*, Feb. 7, 1895, p. 341). He finds that if c and k increase s per cent. per 100deg., then Lord Kelvin's age is multiplied $(1+s/5)^2$ times; *e.g.*, by 121 if $s=50$. His data were due to Dr. R. Weber, and indicated a large increase in c and k with temperature. If correct, Prof. Perry would be fully justified, though to an uncertain extent. But Dr. R. Weber has supplied fresh data which do not show any notable increase in k, whilst that in c is much less than Perry assumed. So Lord Kelvin (*Nature*, Mar. 7, 1895, p. 438) concludes that Perry is wrong. He is also inclined to reduce the initial temperature, and so bring down the age even to 10 million years; or, allowing for other things, to about 24 millions, in agreement with Mr. Clarence King's conclusion in comparing the calculations of Helmholtz, Newcomb, and Kelvin on the age of the sun. It will be interesting to see whether the geologists will continue their downward course to 24 or 10 millions (Sir A. Geikie, *Nature*, Feb. 14, 1895, p. 367, is quite satisfied with only 100), or whether mathematical physicists will, by fresh data, be obliged to go up to meet them.

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London Ph. Trans.-Forcers, stresses & fluxes of energy in t. electromagnetic field, 58 p. /183, 1892/.-

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Nature- Waste of energy from a noving elektron.-Sound waves & electromagnetics the Pan"Potential.-Princ of least action Lagrange's equat.-Princ. of activity & Lagrange's equation, rotat. of a rigid body/67, 1903/.-

Phil. Mag. Eelctromagnetic wave-surf 22 p./19, 1885/.-Self-induction of wires, 160 p./20"24, 1886 & 87/.-Resist. & conductance operators, & their derivatives, inductance & permittance, especially in connexion with electric. & magnetic. energy, 24 p./24,/.- Electromagnetic waves, especially

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